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Estimation of Indicators of Ecological Safety in Civil Engineering

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Abstract

The problem of a complex assessment of potential resource- and energy saving in the civil engineering is unresolved. For achievement of the objectives of ecological protection in the given article the conceptual model of a full resource cycle is offered. It is expedient to carry out calculation of efficiency of construction technologies on the basis of the generalized indicator of ecological safety of the building. An example of a criteria assessment of constructive solutions of civil buildings and results of comparison of their ecological safety is reviewed.

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Keywords: environmental protection, resource-saving, energy-saving, civil structures, civil buildings, the paradigm of biosphere to compatibility.

1. Introduction

Construction is one of the main industries. It is involved in the formation of the techno-sphere. Civic buildings protect people's lives. On average, each citizen of the country produces up to 20 tons of natural resources from which the building is constructed. The obsolete, energy-intensive technologies are used in the construction today. As a result the great quantities of waste are made. The wastes are not disposed of and are not used. The environmental pollution is getting worse [5]. The development pressure is increased on the urbanized territories. The matter of

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efficient resource and cleaner production development is timely. In the Russian Federation this question is listed to the critical technologies. For another thing the project has the social implication [1, 11, 29].

2. The level of knowledge

Problems of complex ecological safety of the construction are described in articles [1, 2, 14]. Publications of Scherbina E.V., Kolchin M. A., Telichenko V.I. [31] are devoted to the peculiarities of the environmental assessment of construction activities. The authors proposed a methodology for forecasting the impact of construction projects on the environment. They schematize solutions of the environmental problems of large cities on the principles of sustainable development. The authors offered to use green building technologies in the Russian Federation.

Russian academy of architecture and construction sciences (Moscow) has proposed an alternative − the paradigm of biosphere to compatibility [3, 11, 13, 20]. The authors of the paradigm (Ilyichev V.A., Bakaeva N.V., Kolchunov V.I., Yemelyanov S.G.) have offered a calculation of the biotecnosphere humanitarian balances that allows harmoniously developing human habitats and preventing crises and catastrophes. The balance equations are derived enabling to determine the required and maximum possible quantities of conventional natural resource matter. The issue of division of technical innovation on progressive and regressive is solved according to their impact on the Biosphere. If the technologies have a negative impact on the natural environment they are regressive.

Questions of resource and energy saving became often the subject of debate in the scientific sphere [16, 17−19]. In the framework of this concept (the paradigm biosphere to compatibility) do not solve the problem a comprehensive evaluation of potential energy efficiency and resource efficiency of civil buildings [7, 8, 32]. It is proposed to consider all life cycle stages of civil buildings: the production of natural raw materials; production of construction materials, civil structures; design; construct a building; maintenance of buildings; removal and disposal of lost property structures [9, 12].

3. The main points

The conceptual model of a complete resource cycle of civil building is proposed to achieve the objectives of environmental protection. The construction wastes are suitable for subsequent resource or energy use in this model. Assessment of environmental safety in civil engineering consists of six indicators [12, 18, 22, 23]:

1) The factor of using non-waste and low-waste technologies (W_n). It characterizes the use of resources in construction (Eq. 1):

$$W_n = \sum(1 - V_{ij} / V_i) \tag{1}$$

V_{ij} – the number of the used i-resource in j - technology material, product, process; V_i – the amount introduced into the process material, product, process of the i-resource.

2) The emission of pollutants into the atmosphere (U_n). This indicator assesses the environmental condition and the level of construction technology. In addition, it reflects the efficiency of environmental activities at the enterprises of the construction industry (Eq. 2):

$$U_n = \sum(1 - \Delta U_i / U_{oi}) \tag{2}$$

U_{oi} – the total emission of pollutants by i -ingredient at the beginning of the forecast period; ΔU_i – reducing emissions of pollutants by i -ingredient at the end of the forecast period due to the introduction of measures to reduce negative impacts on the natural environment.

$$Q_n = \sum(1 - \Delta Q_i / Q_{oi}) \tag{3}$$

3) The rate of discharges into water basins (Q_n). This indicator reflects the technological level of measures to reduce negative impacts on the natural environment and quality of life of the population (Eq. 3):

Q_{oi} – the total discharge of pollutants by i -ingredient at the beginning of the forecast period; ΔQ_i – reducing the discharge of pollutants by i -ingredient at the end of the forecast period due to the introduction of measures to reduce negative impacts on the natural environment.

4) The rate of contamination of soils (S_n). The indicator aims but the assessment of the effectiveness of waste management systems at work, at home, and ecological safety of production (Eq. 4):

$$S_n = \sum(1 - \Delta S_i / S_{oi}) \tag{4}$$

S_{oi} – the number of i-th type of waste at the beginning of the forecast period; ΔS_i – reducing the number of i-th type of waste at the end of the forecast period for the reuse and recycling of waste.

5) The figure of territory (F_n) seized from the nature of the settlement (Eq. 5):

$$S_n = \sum(1 - \Delta S_i / S_{oi}) \tag{5}$$

F_{oi} – the area of settlement at the beginning of the forecast period; ΔF_i – the increase of the area of the settlement by reducing the space occupied by the waste dumps at the end of the forecast period.

6) The energy intensity of building products (EI_n) reflects the consumption of fuel and energy resources throughout the life cycle of the building (Eq. 6):

$$EI_n = \sum(1 - \Delta EI_i / EI_{oi}) \tag{6}$$

EI_{oi} – the total quantity of fossil fuels consumed in the production of construction products at the beginning of the forecast period; ΔEI_i – the reduction of fossil fuel at the end of the forecast period.

The composite index of ecological safety of civil buildings (CI) is determined by the equation 7 under combined action of individual indicators (Eq. 1−6):

$$CI = (W_n \cdot U_n \cdot Q_n \cdot S_n \cdot F_n \cdot EI_n)^{1/6} < 1 \tag{7}$$

The dimensionless characteristics (Eq. 1−7) allow using one method to compare different design solutions of buildings throughout the life cycle. Analysis of the composite index of ecological safety of civil buildings is associated with its reduction due to the corresponding decrease each of the constituent values of selected indicators.

4. Key findings

In the construction industry about 70% of the civil construction is achieved through the application of industrial technologies in Russia. Structural systems of civil buildings have undergone significant changes in the direction of the resource. However, further improvement of such structural systems is not exhausted [6, 15, 21]. For example, in the practice of civil engineering apply constructive solutions to the building frame of the industrial panel elements [4, 10], including load-bearing longitudinal and transverse wall panels connected to the floor slab, self-supporting outer walls are applied. Disadvantages of constructive solutions are as follows: longitudinal and transverse wall panels are made of structural concrete. Structural concrete has a high consumption of materials and energy. Slabs have a high intensity, low sound insulation performance. The intermediate joints of exterior walls may be susceptible to freezing, as they are not insulated and should not have thermal protection [10, 19]. These disadvantages can be eliminated by creating and implementing new industrial energy-efficient and resource-efficient structural systems of civil buildings [25−27] on the basis of the resource cycle low-waste technologies (Fig. 1).

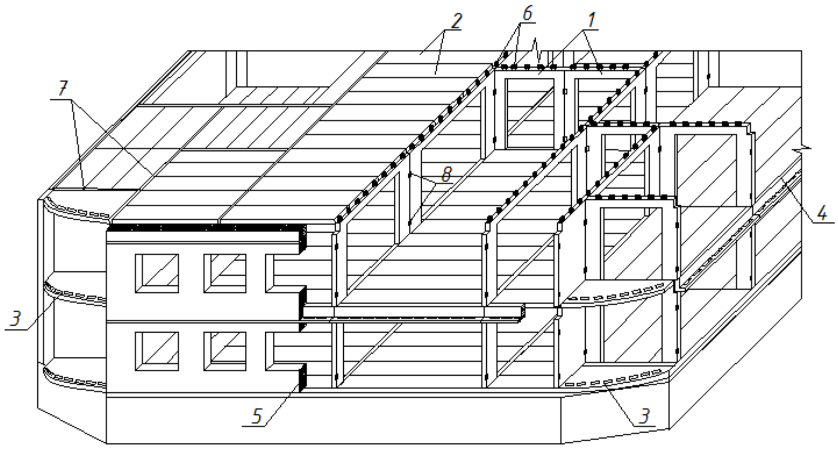

Fig.1. The building of prefabricated elements: 1 - longitudinal and transverse panel-frame; 2 - slabs; 3 - slabs with a perforated edge; 4 - girders with termo-connectors; 5 - outer self-supporting one floor wall; 6 - starter bars; 7 - in-fill concrete; 8 - panels strutting

RAACS and Southwest State University (Russian Federation) are working on the development of the combined structural system of the framework of civil buildings. Designs include: panel-frame bearing elements industrialized production with the completion of a significant part of these elements of energy efficient eco-friendly materials made from two-component (natural materials and by-product). The effectiveness of the new constructive solutions is calculated in Table 1.

Table 1. The results of the calculation of the composite index of ecological safety of civil buildings

No.	The name of the indicators [dimensionless characteristics]	Customary structural concept [10, 19]	The building of prefabricated elements [21, 25−28]
1	The factor of using non-waste and low-waste technologies (W_n)	0.92	0.64
2	The emission of pollutants into the atmosphere (U_n)	0.94	0.72
3	The rate of discharges into water basins (Q_n)	0.85	0.61
4	The rate of contamination of soils (S_n)	0.82	0.59
5	The figure of territory (F_n) seized from the nature of the settlement	0.91	0.76
6	The energy intensity of building products (EI_n) reflects the consumption of fuel and energy resources throughout the life cycle of the building	0.96	0.62
7	The composite index of ecological safety of civil buildings (CI)	0.895	0.653

The indicators of waste products and energy (Table 1) affect the final construction products.

A new constructive solution is characterized by 30% less weight due to the use of thin-walled structural members and high-energy consumption of reinforcing steel, for example, in a horizontal elements by 10−15% (13−20 kg) per 1 cubic meter of concrete in the foundations by 15−20% (15− 35 kg). Through the application of construction projects with lower energy consumption, you can save about 2695−4831 kW·h of electricity per cubic meter of construction volume of the building throughout the life cycle [9, 18].

The overage elements of energy-efficient, resource-efficient structural system after dismantling are returned into the production process as raw material for new constructions at 60−65%.Therefore, the load on municipal landfills is reducing, excluding education of illegal dumping, and storing, for example, urban parks and gardens land.

If we analyze the scheme of "input-output", then we can draw a conclusion. The emissions of carbon dioxide in the atmosphere (12.6 tons per cubic meter of construction volume of the building throughout the life cycle), the discharge of process effluent enter in river basins (4.6 tons), pollution of soils (8.3 tons) are reduced in proportion to the amount of consumption of natural resources.

5. Conclusions

Therefore, the lines of the environmental safety and resource efficient are included:

- replacing the use of natural resources in the industrial waste in the production of construction materials, products, structures [4, 9] and etc.;
- improving the technical and quality characteristic of buildings [19, 21];
- dematerialization of a building or structure;
- improving the durability of the building materials and the life of the structure; modernization and reconstruction [8, 17, 19].

The reduction of energy consumption in the building materials industry through the application of low-technology production, introduction in the construction of buildings of effective thermal insulation materials and structures, design and construction of buildings with efficient systems for heating and ventilation are the lines of the environmental safety and energy efficient.

Considered in the direction of allow a gradual transition from low-waste technologies to technologies full resource cycle in the construction industry [12, 18].

References

[1] Aleksashina, V.V., Ideal'nyj gorod v kontekste filosofii, jekologii i arhitektury [An ideal city in the context of philosophy, ecology and architecture] (2008) Academia. Arhitektura i stroitel'stvo, 3, pp. 41−49. (rus)

[2] Bakaeva, N.V., Shishkina, I.V. Conceptual model of ecologically safe motor transportation system and management problem definition (2013) Jekologija urbanizirovannyh territorij, 2, pp. 64−70.

[3] Bakaeva, N.V. Upravlenie jekologicheskoj bezopasnost'ju avtotransportnoj sistemy goroda na principah biosfernoj sovmestimosti avtoref. Diss. dokt. tekhn. nauk. [Management of ecological safety of transport system of the city on the principles of biosphere compatibility. Dr. tech. sci. diss.] Orel, 2013, 38 p. (rus)

[4] Bondarenko, V.M., Kolchunov, V.I. The concept and directions of development of the theory of structural safety of buildings and structures under the influence of force and environmental factors (2013) Industrial and Civil engineering, 2, pp. 28−31.

[5] Chechevichkin, V.N., Vatin, N.I. Megacities land drainage and land runoff features and treatment (2014) Applied Mechanics and Materials, Vols. 641-642, pp. 409−415.

[6] Cheng, Y., Nin J., Gao N. Thermal comfort models: A review and numerical investigation (2012) Building and Environment, 47, pp. 13−22.

[7] Van Dessel, S., Foubert B. Active thermal insulators: Finite elements modeling and parametric study of thermoelectric modules integrated into a double pane glazing system (2010) Energy and Buildings, 42 (7), pp. 1156−1164.

[8] Dodoo, A., Gustavsson, L., Sathre, R. Building energy-efficiency standards in a life cycle primary energy perspective (2011) Energy and Buildings, 43 (7), pp. 1589−1597.

[9] Golenkov V.A., Kobeleva S.A. The resource-saving technologies and materials in the housing constructions (2012) Building and reconstruction, 2 (40), pp. 74−78.

[10] Dykhovichny, U.A., Kolchunov V.I. Zhilye i obshhestvennye zdanija: kratkij spravochnik inzhenera-konstruktora. Tom 2 [Residential and public buildings: a brief guide the design engineer]. Volume 2 (2011) Moscow, ASV Publ., 400 p. (rus)

[11] Ilyichev, V.A., Kolchunov, V.I., Karimov, A.M., Aleksashina, V.V., Bakayeva, N.V., Kobeleva, S.A. The offers to the draft of the doctrine gradoustroystva and movings (strategic planning of the cities - city planning) (2012) Housing Construction, 1, pp. 2−10.

[12] Ilyichev, V.A., Kolchunov, V.I., Kobeleva, S.A. Criterion model of the resource cycle is the basis of the ecological safety of the construction] (2014) Industrial and Civil engineering, 12, pp. 3−6.

[13] Ilyichev, V.A., Yemelyanov, S.G., Kolchunov, V.I., Bakaeva, N.V. The practice of innovations in cities and urban planning and development doctrine (2014) Biosfernaja sovmestimost: chelovek, region, tehnologii, 3 (7), pp. 3−18.

[14] Ilyichev, V.A., Yemelyanov, S.G., Kolchunov, V.I., Bakaeva, N.V Social expectations, housing programs and quality of life on urbanized areas (2014) Industrial and Civil engineering, 2014, 2, pp. 3−7.
[15] Haapio, A., Viitaniemi, P. Environmental effect of structural solutions and building materials to a building (2008) Environmental Impact Assessment Review, 28 (8), pp. 587−600.
[16] Klingenberg, K. Passive House – a Positive Net Energy Home (2008) ISTC, 10, pp. 37-46.
[17] Kostić, R., Pukhkal, V., Vatin, N., Murgul, V. Application of Styrofoam in the Elements of Building Constructions (2015) Applied Mechanics and Materials, 725-726, pp. 396-402.
[18] Kobeleva, S.A. Assessment of environmental impact of construction projects (2013) Bulletin of Civil Engineers, 3 (38), pp. 277−283.
[19] Kolchunov, V.I. Basic trends in developing structural designs and provision of dwelling safety (2007) Industrial and Civil engineering, 10, pp. 12−14.
[20] Kobeleva, S.A., Bakayeva, N.V., Andreytseva, C.S. Modeling of the housing sphere compatible to the biosphere (2014) Housing Construction, 6, pp. 60−64.
[21] Klueva, N.V., Kolchunov, V.I., Bukhtiyarova, A.S. Resource-energy saving structural system for residential and public buildings with a preset level of structural safety (2014) Industrial and Civil engineering, 2, pp. 37−41.
[22] Kobeleva, S.A. The systematization and identification of the directions of quality standard of the potential of energo- and resource-saving of civil buildings (2014) Building and reconstruction, 5 (55), pp. 61−66.
[23] Kobeleva, S.A. The criteria for the assessment of ecological efficiency of buildings (2013) Building and reconstruction, 5 (49), pp. 47−52.
[24] Marszal A.J., Heiselberg P., Bourrelle J.S., Musall E., Voss K., Sartori I., Napolitano A. Zero Energy Building – A review of definitions and calculation methodologies (2011) Energy and Building, 43, pp. 971–979.
[25] Antonova, M., Glushko, D., Belyaeva, S., Pakrastinsh, L. Comparison of European and Russian Technical Documentation for Structural Use of Concrete (2015) Applied Mechanics and Materials, 725-726, pp. 442-447.
[26] Kolchunov, V.I., Panchenko, L.A. Multiple-core panel. Patent RF, no. 2072411, 2003. (rus)
[27] Ivahnjuk, V.A., Stadolskij, M.I., Osovskih, E.V., Kurbatov, V.L., Evtushenko, E.I. Multilayer wall structure (versions). Patent RF, no. 2153563, 2001. (rus)
[28] Bulgakov, S.N., Suharev, A.A., Kolchunov, V.I. Lightened multivoid panel of prifabricated-monolithic floor. Patent RF, no. 2196207, 2003. (rus)
[29] Popp, D., Hafner, T., Johnstone, N. Environmental policy: Innovation and diffusion of alternative bleaching technologies in the pulp industry (2002) Research Policy, 40, pp. 1253−1268.
[30] Shubin, I.L., Spiridonov, A.V. Problemy jenergosberezhenija v rossijskoj stroitel'noj otrasli [The problem of energy conservation in the Russian construction industry] (2013) Jenergosberezhenie, 1. pp. 15−21. (rus)
[31] Scherbina, E.V. K voprosu jekologicheskoj bezopasnosti stroitel'stva [About the problem of ecological safety of construction] (2009) Academia. Arhitektura i stroitel'stvo, 5, pp. 468−469.(rus)
[32] Thiel, C.L., Campion, N., Landis, Amy E., Jones, Alex K., Schaefer, Laura A.A. Materials Life Cycle Assessment of a Net-Zero Energy Building (2013) Energies, 6 (2), pp. 1125−1141.